ADAPTIVE LINE ENHANCERS FOR FAST CARRIER ACQUISITION - AN API'1.1CA'1'1ON TO TRANSPONDERS

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ABSTRACT

The present spacecraft transponder acquires and tracks the carrier signal by using a phase-locked loop (PLL). Because the frequency sweeping technique is employed in the acquisition process, the time that it takes for the PLL to acquire the uplink carrier is relatively long. The carrier frequency sweeping rate depends on the uplink signal level. For example, the sweeping rate is set to about 40 Hz/sec when the spacecraft receiver signal level equals to -151 dBm for deep space mission. To sweep ± 10 kHz from the best locked frequency, it takes 17 minutes to complete the acquisition process. Therefore, there is a need for fast acquisition technique development with the application to the transponder. In general, a fast acquisition technique will be very useful for deep space missions, especially, in an emergency case. Although devised to support the space mission, the fast acquisition technique proposed in this paper is also applicable to other type receivers, including fixed-ground and mobile receivers.

SLIMMARY

The problem of estimating certain parameters of a sinusoidal signal in the presence of noise is a general interested topic and has received considerable attention in the literature [1 -5]. Examples maybe found in vibration measurements, Doppler radar returns, geophysical processing, and communication systems. Many techniques, such as fast Fourier transform (FFT) and adaptive least squares algorithms, have been proposed in the literature to solve such problems, These methods provide excellent results but may require excessively long time observations because of batch processing.

Recently, time-domain spectral estimation techniques based on adaptive line enhancer (ALE) are introduced [1 -5]. The ALE, which was introduced by Widrow [5], uses the measured signal as desired response and a delayed version of itself as input. The principle is that the delay should decorrelate the noise between the primary and reference inputs while leaving the narrowband carrier signal correlated. When functioning in an ideal way, the adaptive filter output is an enhanced version of the carrier components with higher Carrier-to-Noise Ratio (CNR). The adaptive filter is a time-varying system and the weight vector is updated based on the Least Mean Squares (LMS) algorithm.. The fast measurement of digital instantaneous frequency [1] is one of many applications. In addition, it is well-known that the LMS type algorithms are more robust to sudden variation of the environment parameters than the FFT.

Three adaptive line enhancer (ALE) algorithms and architectures, namely conventional ALE, ALE with Double Filtering (ALEDF), and All with Coherent Accumulation (ALECA) are investigated for fast carrier acquisition in time-domain. The architectures of these three ALEs are shown in Figure 1. The advantages of these algorithms are their simplicity, flexibility, robustness and applicability to general situations including the earth-to-space uplink carrier acquisition and tracking of the spacecraft. In the acquisition mode, these algorithms act as bandpass filters, hence the CNR is improved for fast acquisition. In the tracking mode, these algorithms simply act as lowpass filters to improve Signal-to-Noise Ratio (SNR), hence better tracking performance is obtained, It is not necessary to have a priori knowledge of the received signal parameters, such as CNR, Doppler and carrier sweeping rate. The implementation of these algorithms is in time-domain (as opposed to frequency-domain, such as FFT). The earlier frequency estimation can be updated in real-time at each time sample (as opposed to the batch processing of FFT). The carrier frequency to be acquired can be time-varying, Performance of these ALEs are analyzed. Simulations are conducted for both fixed and swept uplink carrier frequency for the deep space transponder applications. Comparison study shows that the ALECA provides a narrowest spectral peak at the correct earlier frequency among all other acquisition methods including FFT technique.

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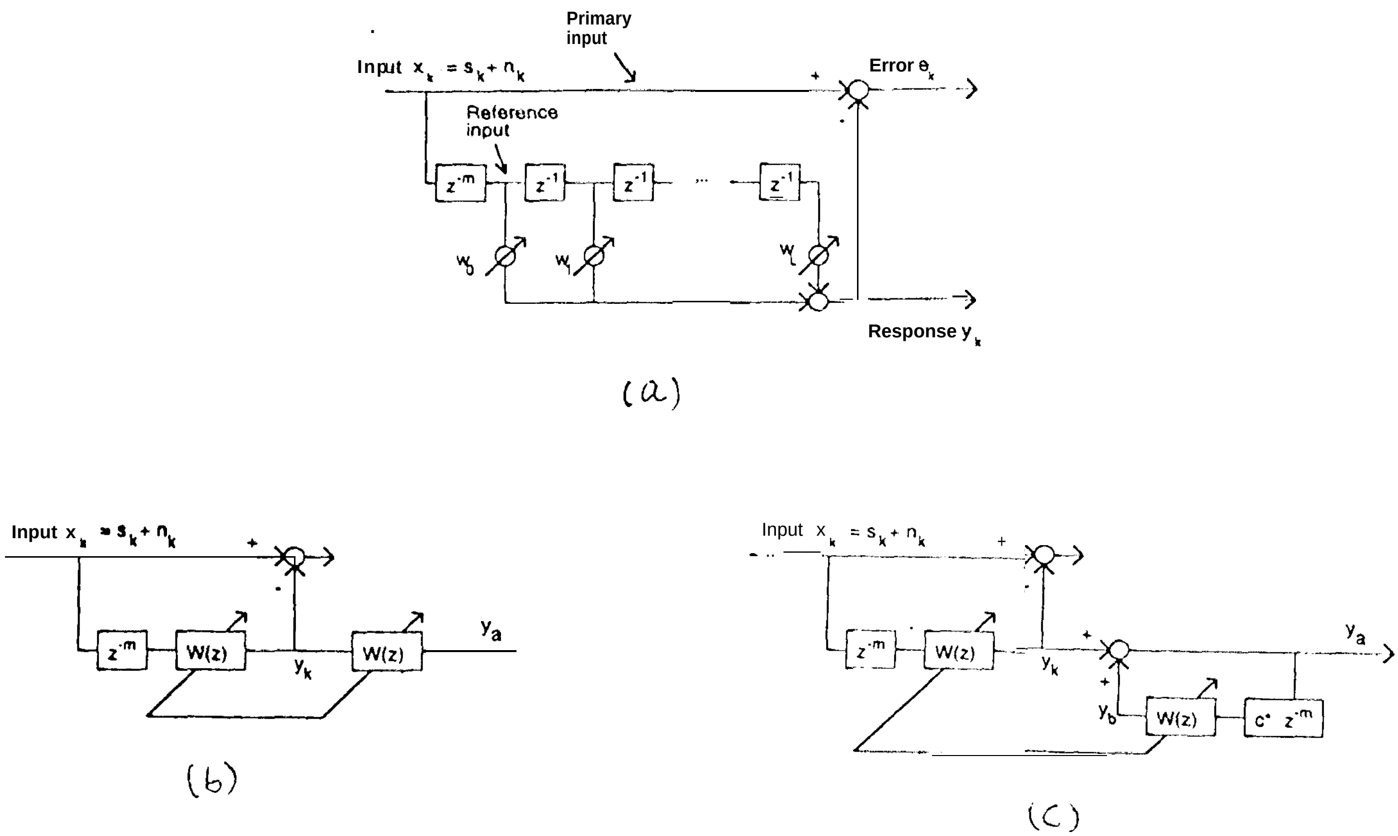

Figure 1. Architectures of the (a) conventional AI .E, (b) ALE with double filtering, (c) ALE with coherent accumulation,